The Role Of Fluid Mud In Sediment Transport Processes Along A Muddy Coast

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LONG-TERM GOALS

The long-term goal of this study is to evaluate the role of fluid mud in sediment transport processes along muddy coastlines. This requires an understanding of the formation and dynamic behavior of fluid muds, as well as the effects on attenuation of surface waves as they approach the shoreline.

OBJECTIVES

The motivation for this study comes from the acknowledgement that work done on sandy beaches is not directly transferable to muddy coasts, and the role of fluid mud is critical to large-scale beach changes on muddy coasts. This study addresses the following objectives:

1. to examine the formation of fluid mud on the inner shelf as the result of a) trapping due to convergence of bottom flows and enhanced settling at a salinity front, or b) a resuspension process due to surface wave activity;
2. to test the concept of a critical bearing capacity for a flow, based on results of Trowbridge and Kineke (1994); and
3. to document the attenuation of wave energy over an inner shelf with fluid muds and relate that to areas of shoreline accretion and erosion.

APPROACH

The study area is the shallow shelf (< 20 m water depth) from Atchafalaya Bay to ~ 100 km west along the western Louisiana coast. Spatial surveys consisting of a series of shore normal transects have been repeated during different river discharge conditions to define the thickness and extent of fluid muds in relation to water properties (extent of freshwater plume and nearshore mudstream). An instrumented profiling tripod capable of measuring flow and fluid characteristics (Sternberg, et al., 1991) and a second, hand-deployable profiler (CTD plus optical backscatterance sensor) for shallow water work have been used. The profiling tripod has been used for spatial surveys (shore normal transects throughout the study area), as well as for tidal and longer time series while the ship is at anchor. The hand-deployable profiler is used off a small boat in water shallower than approximately 5 m. In addition, the small boat is equipped with a dual high frequency echo sounder and differential GPS for mapping thickness and extent of nearshore fluid muds.

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Anchor station time series have been done using the profiling tripod to determine temporal variability and transport on tidal time scales. Simultaneous measurements have been made with pressure sensors to document wave attenuation across the shelf.

A new instrument is currently being tested to document vertical changes in differential pressure, and thus changes in fluid density, from within the mud bed to ~1.5 m above the bed. This will document changes in fluid mud thickness with passage of gravity waves, as well as the appearance of fluid mud due to settling.

The surveys and anchor station measurements are being analyzed to evaluate (1) the influence of river discharge and frontal processes on fluid mud formation and (2) to test the concept of a bearing capacity for a given flow. The pressure sensor array and instrumented differential pressure staff will be used for time-series measurements to evaluate (1) the role of surface gravity waves in fluid mud formation and (2) the effects of the presence of fluid mud on surface gravity wave attenuation.

WORK COMPLETED

The project has been underway for three years and five months. Four cruises have been completed aboard the R/V Pelican: October 1997-low river discharge, March 1998 and 1999 -rising river discharge, high wind activity, and April 1998-high river discharge, diminishing wind activity.

Data collected on these cruises include hydrographic/suspended sediment surveys of 45 stations along seven shore-normal transects, time series measurements of 12-36 hours, shallow water surveys with the echosounder and CTD profiler, and coastal characterization. Wave sensors have been deployed in a cross-shelf array for a three-week time series. A prototype differential pressure staff is currently being tested.

RESULTS

While there are significant differences in the amount of freshwater observed on the shallow shelf from cruise to cruise (season to season), the suspended sediment concentrations are highly variable in space and time and the biggest influence appears to be the wind (and wave) conditions. Observations made in March 1999 focused on these events and concentrated on two types of measurements: 1) high resolution water column profiling at nearshore anchor stations during events, and 2) a time series of wave characteristics on the inner shelf.

Figure 1 shows the evolving sediment and salinity distribution in the water column at two locations at the end of one cold front passage and the onset of a second. A repeated pattern was observed over several days with changing wind speed and direction (not shown). A stratified water column occurs during the weaker, predominant SE winds (JD 64.4-64.8), rapid breakdown of salinity stratification during strong winds from the southwest and high suspended sediment concentrations through the water column (JD 65.5-66.5). As winds switch to the north (around JD 66.5), the nearshore stations are in the lee, and a high concentration bottom suspension forms rapidly through settling which can persist for hours to days. The rapid succession of cold fronts that occurred in March 1999 could have led to the conditions of a persistent fluid mud layer which would significantly affect the attenuation of surface waves reaching the coast.

Three pressure sensors were deployed in a cross-shelf array on the inner shelf in March 1999 (Fig. 2a). Figure 2b shows the significant wave height for these sensors as well as wave data from two weather buoys (National Buoy Data Center, NOAA), in 15 m water depth off the Texas shelf and offshore in 3,200 m in the Gulf of Mexico (Fig. 2a). The five records show the evolution of surface waves during three cold front passages. In each case there is a decrease in wave height (an indicator of wave energy) as the coast is approached where it might be expected to increase prior to breaking on a sandy coast. The significant wave height for the Atchafalaya inner-shelf is less than would be predicted using Linear Wave Theory, and is also less than the NBDC buoy in similar water depth on the Texas shelf. We are investigating these differences as attenuation due to the presence of fluid muds or attenuation over a shallow, gently sloping shelf.

IMPACT/APPLICATIONS

A tremendous amount of research on coastal processes and sediment transport has occurred on sandy beaches; however, muddy coasts are quite common worldwide, especially close to large rivers, and have received relatively little attention by comparison. Wave attenuation is of primary significance for mitigation of shoreline erosion and coastal flooding, and wave attenuation on a muddy coast is directly linked to the characteristics and consolidation state of the muddy substrate, unlike sandy shorelines. In the presence of fluid muds, waves will progressively attenuate as they travel landward, resulting in decreasing boundary shear stresses close to shore, the opposite of what occurs on sandy coasts. Thus, the processes important on sandy beaches are not directly transferable to muddy coasts. The amount of field research done on wave/muddy coast interactions is severely lacking, although a great deal of effort has been done in laboratory flumes and theoretical studies. The field study in progress will provide essential observations for evaluation of the role of fluid muds in sediment transport and our ability to model the effects of wave-mud interaction.

TRANSITIONS

See Related Projects below.

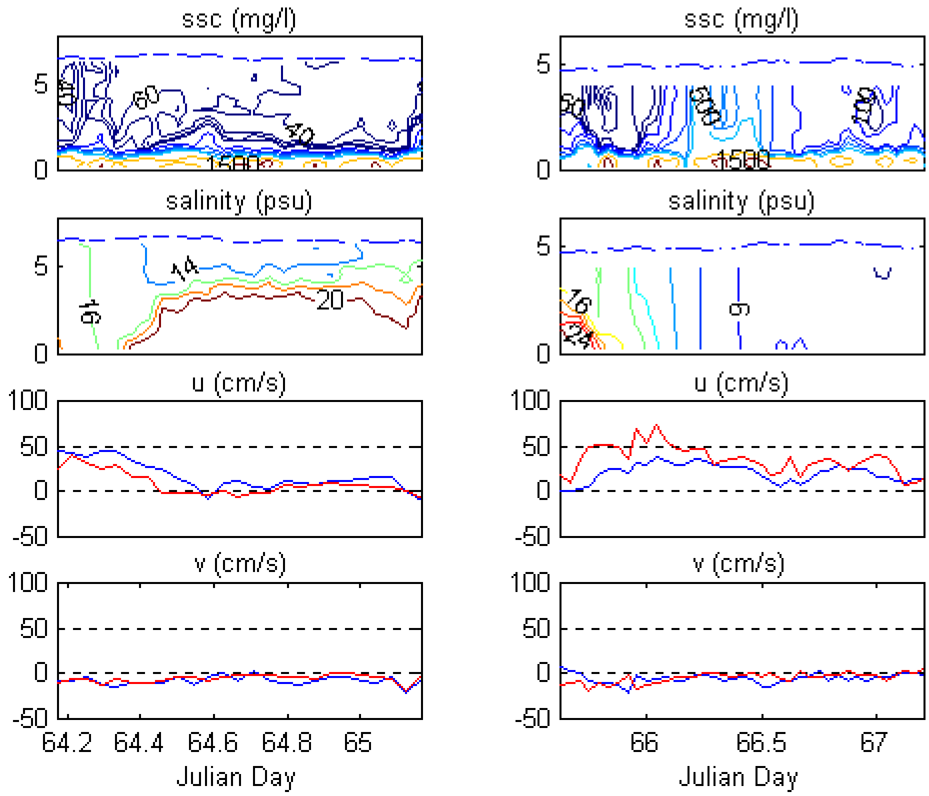

Figure 1. Distribution of suspended sediment (top panels), salinity (second row panels), mean surface and bottom along- and across-shore velocities (third and fourth row panels, u and v, respectively) at two consecutive anchor stations separated by an alongshore distance of 18 km. The high concentration near bottom suspension forms through rapid settling with a decrease in wind speed or a change in direction to the north, and can persist for hours to days. The onset of an event is marked by strong winds from the southwest and high suspended sediment concentrations throughout the water column.

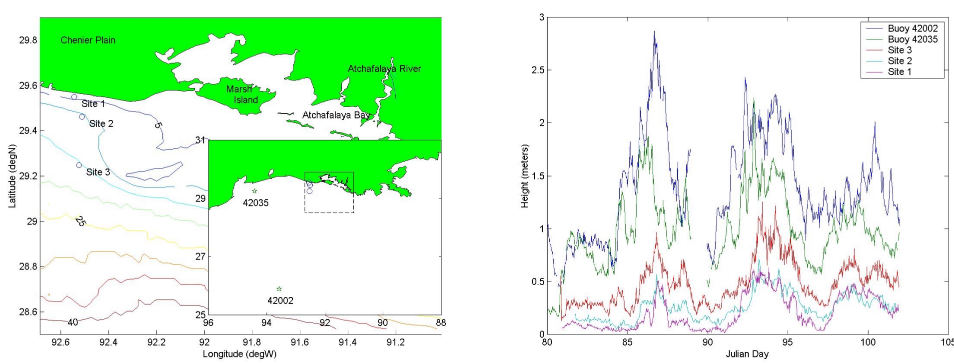

Figure 2. a)Site map showing locations of two NDBC buoys (inset) and three wave sensors deployed for three weeks in March 1999. b) Significant wave height for all five wave records showing three significant events.

RELATED PROJECTS

Sediment Trapping and Transport in Estuaries, Southeastern US, National Science Foundation CAREER Development Program, Kineke PI. This project began in September 1997 and is investigating sediment transport and trapping mechanisms in three estuaries in the southeastern United States

Collaboration with Dr. Miguel Goñi, an organic geochemist (University of South Carolina), began in March 1997. Dr. Goñi and his students have participated in all of our research cruises and collected bottom sediments for organic content and composition analyses. He has been funded by the National Science Foundation to investigate the terrigenous inputs of organic matter to sediments from deeper locations in the Gulf of Mexico (including the outer shelf, continental shelf and abyssal plain). We have coordinated our field efforts and are sharing results allowing for an exciting interdisciplinary component to the ongoing study by analyzing the fate of terrestrial organic matter in marine sediments.

Dr. Brent McKee (Tulane University) has ongoing research in the Gulf of Mexico and the Mississippi and Atchafalaya estuaries (state and federal funding). Ryan Clark, a Ph.D. student of Dr. McKee is using samples from the water column, seabed, and fluid mud layer from our March 1999 cruise to investigate partitioning and exchange of uranium and thorium isotopes in this three component system. The high concentration suspensions are a critical link between seabed and water column chemical exchange.

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